

What is claimed is:

1. An apparatus for brachytherapy comprising:  
 an injection device having a hollow injection needle with an opening at a tip and seed-depositing means for having a radioactive seed pushed therethrough to be deposited in a patient's body through said opening proximal to said tip;  
 5 seed-position detecting means for determining position, with reference to a space-fixed coordinate system, of a seed deposited in the patient's body by said injection device;  
 real-time seed-position determining means for determining position of said deposited seed in real time with reference to a body-fixed coordinate system  
 10 which is affixed to said patient's body;  
 dose calculating means for calculating in real time a radiation dose distribution within a selected volume specified with respect to said body-fixed coordinate system due to seeds which have been deposited by said injection device.

2. The apparatus of claim 1 wherein said seed-position detecting means include:  
 energy transmitting means attached to said injection device for causing energy to be transmitted therefrom;  
 5 a detector at a fixed position with respect to said space-fixed coordinate system for receiving said energy propagated from said energy propagating means; and  
 means for determining position and orientation of said injection device based on the energy propagated from said energy propagating means and  
 10 received by said detector and thereby determining position of said deposited seed from the position of said opening at said tip of said injection needle.

3. The apparatus of claim 1 wherein said real-time seed-position determining means include:

markers affixed to selected parts of said body for defining said body-fixed coordinate system;

5 reference point detecting means for detecting in real time reference point position data with respect to said space-fixed coordinate system on positions of at least portions of said markers; and

referencing means for determining position of said deposited seed with reference to said body-fixed coordinate system from the position of said seed  
10 determined by said seed-position detecting means and the reference point position data detected by said reference point detecting means.

4. The apparatus of claim 3 wherein at least one of said markers comprises a needle with a front end and a back end and inserted in said patient's body, a front end being attached to a radiation transmitting means for transmitting a position-indicating signal for indicating the position of said front end, said back  
5 end being positioned outside of said patient's body so as to be observable by said seed-position detecting means.

5. The apparatus of claim 1 wherein said real-time seed-position determining means includes:  
memory means for storing earlier obtained patient's anatomical data; and  
coordinate-transforming means for identifying said body-fixed coordinate  
5 system with reference to said earlier obtained patient's anatomical data and determining position of said deposited seed with reference to said body-fixed coordinate system from the position of said seed with respect to said space-fixed coordinate system determined by said seed-position detecting means.

6. The apparatus of claim 1 wherein said dose calculating means calculates a hypothetical radiation dose distribution by assuming that a seed has been hypothetically deposited at a hypothetically selected position in said patient's body.

7. The apparatus of claim 1 further comprising injector controlling means for making a comparison between said calculated radiation dose distribution and a predetermined distribution plan, determining a next seed position where a next seed should be deposited in said patient's body according to result of said comparison and controlling said injection device according to said determined next position.

8. The apparatus of claim 1 further comprising display means for providing in real time a visual display of said injection needle with reference to said body-fixed coordinate system as said injection needle is moved through said patient's body.

9. The apparatus of claim 3 further comprising display means for providing in real time a visual display of said reference point position data and the positions of deposited seeds.

10. The apparatus of claim 5 further comprising display means for providing in real time a visual display of said earlier obtained patient's anatomical data and the positions of deposited seeds.

11. The apparatus of claim 3 further comprising memory means for storing earlier obtained patient's anatomical data; and  
updating means for updating said earlier obtained patient's anatomical data by said reference point position data detected by said reference point detecting means.

12. A method in brachytherapy comprising the steps of:  
depositing a radioactive seed in a patient's body through an opening at a needle tip of an injection device;

- 5 determining space-position of said deposited seed with reference to a space-fixed coordinate system;
- determining body-position of said deposited seed in real time with reference to a body-fixed coordinate system which is affixed to said patient's body; and
- 10 calculating in real time a radiation dose distribution within a selected volume specified with respect to said body-fixed coordinate system due to seeds which have been deposited by said injection device.

13. The method of claim 12 wherein the step of determining space-position of said deposited seed includes the steps of:

- causing energy to be propagated from fixed positions on said injection device;
- 5 detecting said propagated energy by a detector at a fixed position with respect to said space-fixed coordinate system; and
- assuming that said deposited seed is located where said opening at said needle tip of said injection device was when said seed was deposited.

14. The method of claim 12 wherein the step of determining said body-position of said deposited seed includes the steps of:

- affixing markers to selected parts of said patient's body;
- detecting said markers in real time by a detector which is affixed at a fixed
- 5 position with reference to said space-fixed coordinate system; and
- determining said body-position of said deposited seed from the detected positions of said markers and said determined space-position of said deposited seed.

15. The method of claim 14 wherein at least one of said markers comprises a needle with a front end and a back end, said front end being attached to a radiation transmitting means for transmitting a position-indicating signal, said

back end being outside of said patient's body, said position-indicating signal being  
5 detected by a space-fixed signal detector.

16. The method of claim 12 wherein the step of determining said  
body-position of said deposited seed includes the steps of:  
retrieving earlier obtained anatomical data on said patient's body;  
determining said body-fixed coordinate system from said earlier obtained  
5 anatomical data; and  
determining said body-position of said deposited seed from body-fixed  
coordinate system and said determined space-position of said deposited seed.

17. The method of claim 12 further comprising the steps of calculating  
hypothetical dose distribution by assuming that a seed has been hypothetically  
deposited at selected positions inside said patient's body and causing said  
calculated hypothetical dose distributions to be displayed.

18. The method of claim 12 further comprising the steps of:  
making a comparison between said calculated radiation dose distribution  
and a predetermined distribution plan;  
determining a next seed position where a next seed should be deposited in  
5 said patient's body according to result of said comparison; and  
controlling said injection device according to said determined next  
position to inject a next seed at said determined next seed position.

19. The method of claim 12 further comprising the step of displaying  
an image of said injection needle in real time with reference to said body-fixed  
coordinate system as said injection needle is pushed through said patient's body.

20. The method of claim 14 further comprising the step of displaying in real time the positions of said markers and positions of seeds which have been deposited by said injection device.

21. The method of claim 16 further comprising the step of displaying in real time said earlier obtained anatomical data on said patient's body and positions of seeds which have been deposited by said injection device.

22. The method of claim 14 further comprising the steps of updating earlier obtained anatomical data on said patient's body by using the positions of said detected markers.

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